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ABSTRACT

Critically reviewed evidence relevant to hypotheses of biological sources of sex-related cognitive differences as they relate to mathematics achievement include the following: explanations based on the assumption of greater variability in male cognitive performance; sex-related differences in serum urate; effects of estrogens compared to androgens on cognitive functioning; recessive X-linked hypotheses of the inheritance of mathematical problem solving and spatial visualization, and hypotheses of sex-related differences in brain lateralization, including how they relate to rate of maturation. Empirical support of these hypotheses is weak and mostly inconsistent with available data. Some tentative support was found for the role of earlier left cerebral dominance in females as a factor, interacting with educational and cultural experiences, which could lead more females than males to emphasize a verbal, analytic rather than a spatial, gestalt approach. Research implications are discussed. An annotated bibliography is included. (Author)

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SUMMARY OF EFFECTS OF BIOLOGICAL FACTORS ON SEX-RELATED DIFFERENCES IN MATHEMATICS ACHIEVEMENT[1]

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This paper presents a very brief summary of the overall literature review. I would like first to consider some historical and conceptual points and then I would like to discuss briefly the major relevant hypotheses.

It is widely believed that women are not so intellectually competent as men.[3] It is especially believed that women are inferior in mathematics and science. These beliefs, which have been common throughout recorded history, have been accompanied by disbelief when women perform well intellectually. Such performances are often attributed to luck, or to grinding hard work, but not to ability. These distorted attributions occur in men and women alike.[4] Historically the belief that women are not so intellectually competent as men has often been accompanied by the belief that women should not be as intellectually competent as men,[5] but one rarely hears this viewpoint baldly expressed in contemporary society.

With the increasing social importance of science in the 19th century, scientific explanations for supposed female intellectual inferiority became popular. One of the most commonly believed was that women were intellectually inferior to men because their brains are smaller.[6] Subsequently brain size, in the normal ranges, has been found to be uncorrelated with intelligence. Another common belief was that the womb draws energy away from the brain.[7] Not only did this view attempt to account for inferior female intelligence, but it also contained the implication that intellectual work would damage women's reproductive capacity and health. In this way it served as a rationale to keep women away from education and intellectual work "for their own good."

In the United States in the 1970's views of women's iferiority in intelligence and in status have been challenged by a call to the ideals of our constitution and democratic heritage of equality of opportunity. It is well, however, to remain cognizant of the perspectives of history. Biological explanations of female intellectual inferiority which now seem foolish have been well respected scholarly views during their time.[8]

The task of this paper is to consider biological explanations for sex-related differences in mathematics performance, but is there a difference between the sexes in mathematics performance? As sex role behaviors have been less rigidly defined and enforced, sex-related differences have decreased and in many instances they have not been demonstrated.[9] While many researchers continue to report sex-related differences in mathematics performance, a large, carefully controlled study of sex-related differences in mathematics performance found differences in favor of males in only 1 of 9 schools in grades 6 to 8 and 2 of 4 schools in grades 9 to 12.[10] When differences were found, they were small and, contrary to common expectation, they did not increase with the difficulty of the material. It could be argued that the reason sex-related differences were not always found at the high school level was that the girls were a more select group than the boys. This argument, however, does not explain why students at two high schools showed sex-related differences in math performance while students in two other high schools did not although the

selection procedure was the same in all four schools. Demonstrated school variations in sex-related socio-cultural factors offers a more likely explanation, than that two samples of girls were somehow more intellectually select than the boys. It is beyond the scope of this paper to review the literature on sex-related differences in mathematics performance, but it should be noted that hypotheses to explain sex-related differences in mathematics performance may be attempting to explain a phenomenon which ultimately is found not to exist.

Let me share with you now the results of my review of the literature on the effects of biological factors on sex-related differences in mathematics achievement. I identified and evaluated five different hypotheses of biological sources of sex-related cognitive differences as they relate to mathematics achievement. These hypotheses are: The assumption of greater variability in male cognitive performance; sex related differences in serum urate, what I call the gout hypothesis; hormonal hypotheses related to the effects of estrogens compared to the effects of androgens on cognitive functioning; the recessive X-linked hypotheses of the inheritance of mathematical problem solving and spatial visualization, and hypotheses of sex-related differences in brain lateralization. Now I would like to describe each of these hypotheses and briefly summarize the evidence relevant to each.

The variability or dispersion hypothesis is the oldest. It basically states that males are more variable in intelligence than females so that there are more geniuses and more mental defectives among males than among females. The major question in evaluating this hypothesis is what kind of evidence is acceptable and relevant. It was recognized at a very early point that to test this hypothesis adequately one must have a complete sample of a particular population. Needless to say this is very difficult to do. The best data that are available are from Scotland during the 1930's.[11] These data, however, are of limited value in assessing the variability hypothesis as applied to mathematics since the tests used were largely verbal in nature. Neither spatial visualization nor mathematical problem solving were assessed by these tests. These data then apply most appropriately to the distribution of general intelligence or to the distribution of verbal intelligence. Males did appear to be more variable in intelligence, but the increase in variability came from the presence of more males at the lower end of the distribution. That is, while there were no more male geniuses than female geniuses, there did appear to be more male mental defectives than female mental defectives.[12]

If one were able to gather data on spatial visualization and/or mathematical problem solving, in a complete population, it would be of some interest. However, if one found greater male variability, in order to infer a genetic source for the difference, one would have to be able to rule out experential differences in the background of the two sexes. That would not be easy. One should also note that if one establishes that males are more variable, one is still left with the question of why.

The second hypothesis that I studied was recently presented in the textbook of Hyde and Rosenberg[13] and is what I call the gout hypothesis. Gout as you probably know is a metabolic disease characterized by elevated levels of uric acid in the blood and its deposit as a salt in various parts of the body, notably in the joints or as kidney stones. These deposits can be a source of extreme pain and interfere with function. Well, it seems that geniuses are especially prone to gout and that females have less uric acid in their blood than males, ergo the hypothesis that there are fewer female than male geniuses

because of lack of uric acid. However uric acid level is not correlated to any important extent with intelligence.[14] Uric acid level may be related to ambition but the evidence is very shakey indeed that uric acid level causes people to be ambitious and striving. It may well be instead that being extremely ambitious raises serum uric acid level. While gout is a very interesting metabolic disease, I do not think research in this area will shed much light on sex-related cognitive differences.

The third hypothesis that I investigated is the hormonal hypothesis of Broverman, Klaiber, Kobayashi and Vogel.[15] Basically this hypothesis states that simple repetitive tasks benefit from high levels of activation while complex restructuring tasks, which would include most mathematical tasks, benefit from low levels of activation. The hypothesis further states that since estrogens are stronger activators than androgens, females are better at simple repetitive tasks while males are better at complex, restructuring tasks. I am going to leave aside a host of conceptual and empirical criticisms and focus instead on data that provide a direct test of the hypothesis.

Ordinarily, of course, one does not manipulate hormone levels in human subjects. In human females, however, estrogen levels normally vary with the phase of the menstrual cycle. Two recent studies provide relevant data. I should mention, however, that these studies were not designed to test the Broverman et al. hypothesis and that the authors did not discuss their data in relationship to it. Englander-Golden and her colleagues[16] found that when estrogen level was high (mid-cycle), performance on a simple repetitive task (Digit Symbol) was no better than when estrogen level was low (during the premenstrual and menstrual phases). Likewise estrogen level was not related to performance on a complex, restructuring task (Spatial Relations). Zimmerman and Parlee[17] also found no menstrual phase differences in digit symbol performance. These results are totally inconsistent with the Broverman et al. hypothesis and disconfirm it. The general area of hormones and cognition is very interesting, but as yet there is much speculation and several false starts but little solid evidence to indicate that hormones are related to differences in cognition between the sexes.

The fourth hypothesis is the X-linked hypothesis of the inheritance of spatial visualization and mathematical problem solving.[18] Basically the X-linked hypothesis is that high potential is carried as a recessive characteristic on the X chromosome. If the X linked hypothesis were true, it would mean that many more males than females would evidence high potential. Since it is now clear that these hypotheses are false, I am not going to go into further detail about them. The negative evidence has accumulated in the last two years and some of it is still unpublished. Disconfirmation comes from four independent research groups: DeFries and his colleagues, Williams, Bouchard, and Sherman and Fennema.[19]

What I have called the fifth hypothesis is really a whole set of hypotheses having to do with brain lateralization. Before describing and evaluating the various hypotheses, however, I would like to discuss very briefly the relationship of mathematics functioning to the two hemispheres of the brain. In normal, right-handed persons, the left side of the brain is supposed to control verbal, analytic function and the right side of the brain is supposed to control spatial, gestalt function. As is probably immediately obvious to you, advanced forms of mathematics, frequently involve <u>both</u> sides of the brain. The hypotheses of sex-related differences in laterality of the brain are most pertinent to mathematics in relationship to the relative development of spatial visualization skills.

There are at least five identifiable hypotheses regarding sex-related differences in brain laterality. Buffery and Gray's[20] hypothesis states that males have more bilateral representation of spatial function than females and that therefore males have better developed spatial skill. There is almost no evidence of greater male bilaterality of spatial function, nor is it clear that bilaterality of function is favorable. This hypothesis lacks empirical support.

Jerre Levy[21] has hypothesized that females have poorer spatial skill than males because their verbal function is more bilateral than verbal function in males. She sees this verbal bilaterality as interfering with maximal hemispheric specialization therefore leading to poorer spatial performance in females than in males. Levy sees female performance as like that of left-handed males who are known to be characterized by verbal bilaterality. There is little evidence of more bilateral verbal function in females than in males and female cognitive performance is not similar to that of left-handed males. The Levy hypothesis also lacks empirical support.[22]

Harshman and Remington[23] account for cognitive sex-related differences with the hypothesis that males are more lateralized than females for both verbal and spatial function. As already mentioned, evidence of greater female bilaterality of verbal function is very sketchy so that the Harshman and Remington view is also not supported.

I have suggested the bent twig hypothesis, namely that females more than males come to rely on the verbal, analytic mode because of the relative verbal precocity of females, the verbal emphasis of our educational system, and experiences related to sex role which benefit the spatial development of males more than females. This hypothesis is still viable.[24]

Waber[25] has hypothesized that brain lateralization and spatial skill is favored by late maturation and that since boys mature later than girls, boys typically show superior spatial skill. Petersen,[26] however, did not confirm her findings. It is too early yet to come to a firm conclusion about this hypothesis.

There is a great deal of activity in this research area and it is in a state of rapid movement. It is possible that females would benefit from explicit right hemisphere training. In fact it seems to me that the teaching methods used by Nancy Kreinberg at the Lawrence Hall of Science and by Lenore Blum at Mills College are right hemisphere training. Here I refer to their emphasis on estimation and on graphs and on requiring visualization of the graph without the use of a formula. It would be interesting to compare the performance of women taught with techniques emphasizing visualization with the performance of those taught without such emphasis. This particular research area may prove to be fruitful.

In general, however, what can one conclude from all this research? I think one can conclude that people continue to be very fertile in providing biological explanations for cognitive sex-related differences. I must also say that the quality of much of the research was very poor. I think we can also conclude that although sexism has become unfashionable, there continues to be a strong need for people to become aware of their biases and to exercise caution in the interpretation and promulgation of research concerning sex-related cognitive differences.

Footnotes

[1]This summary is based on a project contracted by the National Institute of Education, Contract Number 400-76-0113. Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Institute of Education. A limited nuber of the complete manuscript is available from Dr. Judith M. Sauls Shoemaker, National Institute of Education, Department of Health, Education and Welfare, Washington, D. C. 20208. The complete manuscript and annotated bibliography is to be published. The present paper is only a very brief summary of the entire manuscript.

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[5]For a sample of historical views see O'Faolain,J., & Martines, L. (eds.) Not in God's image. New York: Harper & Row, 1973.

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[19]In addition to the Stafford articles, the main supporting article is Bock, R. D., & Kolakowski, D. Further evidence of sex-linked major-gene influence on human spatial visualizing ability. American Journal of Human Genetics, 1973, 25, 1-14. The recent disconfirming studies include DeFries, J. C., Ashton, G. C., Johnson, R. C., Kuse, A. R., McClearn, G. E., Mi, M. P., Rashad, M. N., Vandenberg, S. G., & Wilson, J. R. Parent-offspring resemblance for specific cognitive abilities in two ethnic groups. Nature, 1976, 261, 131-133; Williams, T. Family resemblance in abilities: The Wechsler Scales. Behavior Genetics, 1975, 5, 405-409; Bouchard, T. Sex differences in human spatial ability: Not an X-linked recessive gene effect. Manuscript submitted for publication, 1976; Sherman, J. & Fennema, E. Distribution of spatial visualization and mathematical problem solving scores: A test of Stafford's X-linked hypotheses. Manuscript submitted for publication, 1977.

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[22]See the complete manuscript for a fuller discussion of these hypotheses. It is impossible to condense the argument and evidence adequately for this paper.

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